The University of Chicago

THE GEOLOGY AND PARAGENESIS OF THE NICKEL ORES OF THE CUNIPTAU MINE, GOWARD NIPISSING DISTRICT, ONTARIO

A PART OF A DISSERTATION SUBMITTED TO THE FACULTY OF THE DIVISION OF THE PHYSICAL SCIENCES IN CANDIDACY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY AND PALEONTOLOGY

1943

By

BENNETT T. SANDEFUR

Reprinted from

Economic Geology, Vol. XXXVII, No. 3,
May, 1942

The University of Chicago

THE GEOLOGY AND PARAGENESIS OF THE NICKEL ORES OF THE CUNIPTAU MINE, GOWARD NIPISSING DISTRICT, ONTARIO

A PART OF A DISSERTATION SUBMITTED TO THE FACULTY OF THE DIVISION OF THE PHYSICAL SCIENCES IN CANDIDACY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY AND PALEONTOLOGY

1943

By

BENNETT T. SANDEFUR

R. UNIV. BIBLIOTHEEK LEIDEN

Reprinted from

Economic Geology, Vol. XXXVII, No. 3, May, 1942

Digitized by the Internet Archive
in 2026

https://archive.org/details/IA41544324_0109

THE GEOLOGY AND PARAGENESIS OF THE NICKEL ORES OF THE CUNIPTAU MINE, GOWARD NIPISSING DISTRICT, ONTARIO.

BENNETT T. SANDEFUR.

ABSTRACT.

This is a detailed description of a nickel deposit near Goward in the Timagami Provincial Forest 300 miles north of Toronto, Ontario. The general geology of the Cuniptau mine is comparable to that of many other mining areas of that section of Ontario. Lying on the deeply eroded surface of a basement complex is a great thickness of Keewatin lavas. After their extrusion they were folded, faulted, and intruded by peridotite. A long period of alteration and erosion followed, before the final intrusion of many small Keweenawan dikes. It is concluded that the Keweenawan intrusives had no part in the mineralization at Cuniptau mine. This is a case where post-magmatic solutions deposited the copper and nickel sulphides. The important and abundant nickel-bearing sulphide is the secondary nickel sulphide violarite, which may make this nickel deposit one of the first mined in which secondary enrichment has played an important role.

INTRODUCTION.

THE name *Cuniptau* is interesting because it is the combination of symbols representing the important metallic elements obtained from the mine, that is Cu, Ni, Pt, and Au.

This property of the Ontario Nickel Company consists of a group of claims in the northwest half of Strathy Township, Nipissing District, Ontario. This township, located in the Timagami Provincial Forest three hundred miles directly north of Toronto, is reached by the Temiskaming and Northern Ontario Railway. The recently completed Ferguson Highway passes through Goward, making it possible to drive by car to the Cuniptau mine.

The author is indebted to the officials of the Ontario Nickel Company, especially to Mr. B. W. Watkins, President, Mr. Walter Watkins, Secretary, to Mr. H. G. Watkins, the original staker of the property, and to Mr. George M. Lee, Superintendent

of the Cuniptau Mine. To Drs. Edson S. Bastin, Norman L. Bowen, and Francis J. Pettijohn, the writer wishes to express his gratitude for their visit to the property during the field season of 1937, and his appreciation for their valuable advice and criticism.

The Cuniptau mine lies within the irregular surface of the deeply-eroded, pre-Cambrian Canadian Shield, where Keewatin "greenstones" exhibit less relief than the younger intrusives. The numerous lakes of the region trend in a northeast, or in a northwest, direction, and probably follow two major fault systems. The northeasterly trending arms, parallel to the general strike of the pre-Cambrian "greenstones," may indicate that erosion was controlled by strike faults resulting from deformation of the "greenstones."

GENERAL GEOLOGY.

As this area is a part of the same area described by E. W. Todd,[1] the following passage from his report is quoted:

> With the exception of the Timiskamian series, all the rock formations found in the pre-Cambrian of northeastern Ontario are represented in this area. The geology is there similar in many respects to that of the well-known area of Cobalt. . . .

Only the Keewatin volcanics (greenstones), the Haileyburian peridotite, and the Keweenawan olivine-diabase dikes are of importance in the geology of the mine.

STRUCTURE.

The highly-folded Keewatin lava flows of the Cuniptau area have a distinct N 20 E strike, and a steep dip, which ranges from 60 to 80 degrees. The folding of these flows caused strike faults that roughly parallel the structural trend of the folded lavas. The hollow in which Cuniptau Lake is situated probably is developed along a large fault, although the fault cannot be detected on the surface. Some younger diabase dikes that cross the valley bot-

[1] Todd, E. W.: Anima-Nipissing Lake Area. Ontario Dep. Mines, XXXV, Part III: 84, 1926.

toms appear to have been displaced laterally, indicating a northward movement of the east side.

Numerous altered peridotite masses intrude the Keewatin lavas and outcrop as prominent ridges and knolls. Since these cut across the strike of folded Keewatin lavas, they are later in age than the folding and faulting.

There are two well-defined systems of fractures in the mine, one northwesterly and the other northeasterly. The former is the stronger, and dips 30° to 60° E.

ORE OCCURRENCE.

The largest ore bodies occur in a shear zone produced by the fracture systems. The gossan extends along it for 300 feet and drifting on the first three levels for 250 feet from the shaft has been in the richest zone yet developed. East and west from this rich zone, there are numerous fractures that carry calcite and rare masses of sulphides from 1 to 6 inches across. Between these stringers ore minerals are disseminated through the serpentine, and even in the greenstones. Drill cores yield no evidence that the disseminated mineralization is related to the vein system; the disseminated material is not appreciably richer close to the stringers. It seems that the best ore was localized by well-developed, pre-mineral fractures.

PETROLOGY.

Keewatin Lavas.

The predominating rocks outcropping on the Cuniptau property are locally known as "greenstone," which includes basic and acid lava flows, amygdaloidal basalts, pillow lavas, agglomerates, vesicular lavas, and pyroclastics. These Keewatin rocks form a complex into which the younger rocks have been intruded. Both the basic and acid flows contain disseminated specks of sulphides. This is quite characteristic of all the flows, especially those in the vicinity of the mine.

Rhyolite.—This variable rock is generally more schistose than the associated basaltic flows. It is a fine-grained, uniform,

microfelsitic rock of a gray to yellow-green color, which weathers white on the surface. Microscopically, it is much altered and consists of quartz, plagioclase (albite-oligoclase), and orthoclase, with secondary white mica, talc, kaolin, chlorite, calcite, and hematite. Large patches of pyrite consist of well-defined crystals closely associated with chlorite.

Andesite.—This rock is the typical "greenstone" of the pre-Cambrian, and is generally smooth, fine-grained, and even-textured, with grayish-green to chlorite green color. It is not markedly schistose. The essential minerals are albite-oligoclase, and orthoclase. Secondary white micas, kaolin, and chlorite nearly mask the original feldspars of the groundmass. Ferro-magnesium minerals, common in most normal andesites, appear to be absent, and the chlorite present does not show the outline characteristic of that altered from ferro-magnesian minerals.

Dacite.—Dacite is not common in the Cuniptau area. Darker varieties resemble the andesites in the field, but they do contain a small amount of quartz. The dacite is a dense, fine-grained, grayish-green rock, slightly coarser-grained and not as smooth on the surface as most of the lavas. Under the microscope it is seen to be porphyritic and the primary minerals are quartz and andesine, with minor amounts of hornblende and magnetite. Chlorite occurs as a replacement of the original phenocrysts and as irregular fillings in vugs. Calcite is closely associated with secondary vein quartz.

Amygdaloidal Lavas.—Amygdaloidal greenstones are less abundant than the non-amygdaloidal type, and are more fractured and schistose than the other lavas. Flattened amygdules of calcite, quartz, and chlorite, make up 20 to 25 per cent of the exposed surface. Where the outcrops have been exposed for some time, the surface resembles a "worm-eaten" rock, due to empty vesicules. The microscope reveals that the groundmass is slightly more coarse-grained than most of the lavas of the region. The rock is holo-crystalline, equi-granular, felspathic, and possesses a bostonitic texture. The feldspars, composing at least 80 per cent of the groundmass, occur as long, narrow crystals, slightly al-

tered, but retaining most of their original form. The outlines of the patches of chlorite are too poorly defined to determine the particular primary mineral.

Breccia-agglomerate.—This rock is dark-greenish or greenish-gray in color. It is a massive volcanic breccia with negligible schistosity. The coarser fragmental material is arranged in a heterogeneous manner. Most of the fragments are more or less rounded, but may be subangular or angular.

Haileyburian Peridotite.

General.—Numerous masses of serpentinized rock outcrop on the Cuniptau property and have been called Haileyburian or pre-Algoman in age.[2]

The relative age of the serpentinized masses and the other formations in the vicinity of Cuniptau mine is known since these masses definitely cut the older Keewatin "greenstones," whereas the serpentine itself is cut by the younger Keweenawan olivine-diabase dikes.

The peridotite masses form small, elongated, or rounded hills above the surrounding Keewatin lavas. Where this rock intrudes the Keewatin flows, the lavas are schistose near the contact and, under the microscope, exhibit alteration. This rock carries the massive sulphides of Cuniptau mine. A gossan, forming a rusty, low, smooth knoll, into which the shaft is sunk, is entirely within the completely serpentinized rock. Locally this altered rock is known as the "old Diabase" or the "serpentine." The latter is more appropriate.

Altered Haileyburian Peridotite.—The altered peridotite is a dense, black rock, which appears deceivingly fresh to the eye. Most specimens are a coarse, gray-green, serpentinized rock, the secondary minerals of which exhibit definite crystal outlines. The presence of small crystals of pyrite, found in all of the altered, serpentinized peridotite, can be used to distinguish between

[2] Knight, C. W.: Windy Lake and other nickel areas. Ontario Dept. Mines, XXIX, Part I: 209, 1920. Todd, E. W.: op. cit., p. 89.

the pre-Algoman and the post-Algoman rocks, since they are absent from the Keweenawan dikes.

The microscope reveals that at least 80 to 90 per cent of the primary minerals are now altered to chlorite, talc, and serpentine. The skeleton outlines of the secondary magnetite, and the characteristic mesh structure of the serpentine probably indicate that the most important primary mineral was olivine. Two secondary amphiboles, tremolite and anthophyllite, are present. Some titaniferous augite remains as interstitial fillings between the serpentinized olivine grains.

Keweenawan Dikes.

The only rocks of Keweenawan age near the Cuniptau mine are olivine-diabase dikes that strike east-west across all of the older formations. They are later than the folding and faulting of the "greenstones." All Keweenawan dike rocks have a distinctly rusty appearance upon the exposed surfaces, whereas the fresh specimens taken from the interior have a dark-gray to black color.

Olivine-diabase Dikes.—Except for texture, all of the Keweenawan dike rocks are similar, and their freshness permits distinction from the older rocks. This grain size ranges from very fine along chilled borders to coarse-grained in the center, and they possess ophitic texture with titaniferous augite molded between laths of plagioclase (Fig. 1).

The most abundant primary minerals are labradorite, augite, olivine, magnetite, ilmenite, and apatite; lesser biotite and hypersthene are present. The secondary minerals include kaolin, sericite, or perhaps paragonite, hematite, magnetite, serpentine, biotite, and chlorite. The olivine is fresh and unaltered in contrast to the completely decomposed olivine of the Haileyburian peridotite, indicating a difference in age (Fig. 2).

Gangue Rocks.

General.—The gangue is a highly altered, schistose, fractured, soft, grayish-green to dark-green serpentine, and the outcrops are permeated with iron oxides and copper carbonates.

Altered Gangue Rocks.—Thin sections of the sulphides and associated gangue rocks show similar characteristics, inasmuch as all are extremely altered, with little or no trace of the original rock minerals. Pseudomorphs of serpentine after olivine are outlined by magnetite. Carbonates, consisting of calcite, dolomite, and magnesite, are the most abundant secondary minerals. The sulphides follow the cleavage planes and enclose carbonate crystals, indicating that most of the sulphide mineralization is later than the greater part of the carbonate deposition. Chlorite, in bladed form, may replace calcite. Some of the sulphides are also blade-like in form, apparently indicating that they replaced some of the chlorite or were deposited between chlorite blades. In one section, blades of sulphides have been replaced by a secondary silicate. Well-developed flakes of talc are abundant; some replaces calcite. The secondary hornblende, uralite, is also present (Figs. 8, 10).

MINERALOGY OF THE ORES.

About 35 polished specimens were studied microscopically by the reflecting microscope, and the metallic minerals were determined in the usual manner aided by microchemical tests.

The most important ores are sulphides of copper, iron, and nickel, with chalcopyrite the most abundant, followed by pyrrhotite. Pentlandite, pyrite, marcasite, magnetite, chromite, and sphalerite occur in varying amounts. The most important nickel-bearing mineral is violarite.

Pyrrhotite.—Pyrrhotite is associated with chalcopyrite and pentlandite, and contains inclusions of rounded, partly replaced, and irregular areas of magnetite and pyrite. The pyrite, but not the magnetite, has been replaced by the pyrrhotite. The pyrrhotite has grown around and into fractures of broken blades of chlorite indicating that the chlorite suffered deformation before the sulphide mineralization occurred. The pyrrhotite surrounds and is later than most of the carbonate rhombs (Figs. 5, 3, 9).

Chalcopyrite.—Chalcopyrite occurs disseminated throughout most of the altered peridotite mass. It is prevailingly associated

with pyrrhotite, but in a few places it is the only metallic mineral of the ore. An odd occurrence of chalcopyrite was noted, in which it envelops radiating chlorite crystals and occupies fractures across them. Chalcopyrite in places contains blebs of sphalerite, pyrrhotite, and pentlandite, that appear contemporaneous with the chalcopyrite, but in general, the chalcopyrite is younger than these minerals. Along the contact of individual crystals of talc and calcite, long, narrow blades of chalcopyrite are present indicating that the gangue was completely altered before the chalcopyrite was introduced. Stringers of chalcopyrite cross pyrrhotite and pentlandite, and follow their outlines, indicating a later age (Figs. 6, 4).

Pentlandite.—Pentlandite is the most abundant nickel-bearing mineral of the ores. An interesting feature of this nickel sulphide is that it alters readily to the secondary nickel sulphide "violarite." Pentlandite is present in varying amounts, occurring most abundantly with the massive pyrrhotite and in lesser amounts in the pyrrhotite-chalcopyrite ores. Two types of pentlandite are present: (1) Smooth, nearly white, flame-like streamers extending through pyrrhotite; (2) pinkish-yellow, rough fractured, massive mineral. The latter tends to develop what are interpreted as shrinkage cracks. Along these fractures the pentlandite is altered to supergene violarite. Hematite commonly fills the larger fractures of the pentlandite (Figs. 3, 9).

Fig. 1. Typical texture of fresh Keweenawan dike rock with titaniferous augite and magnetite molded between plagioclase laths. × 20.

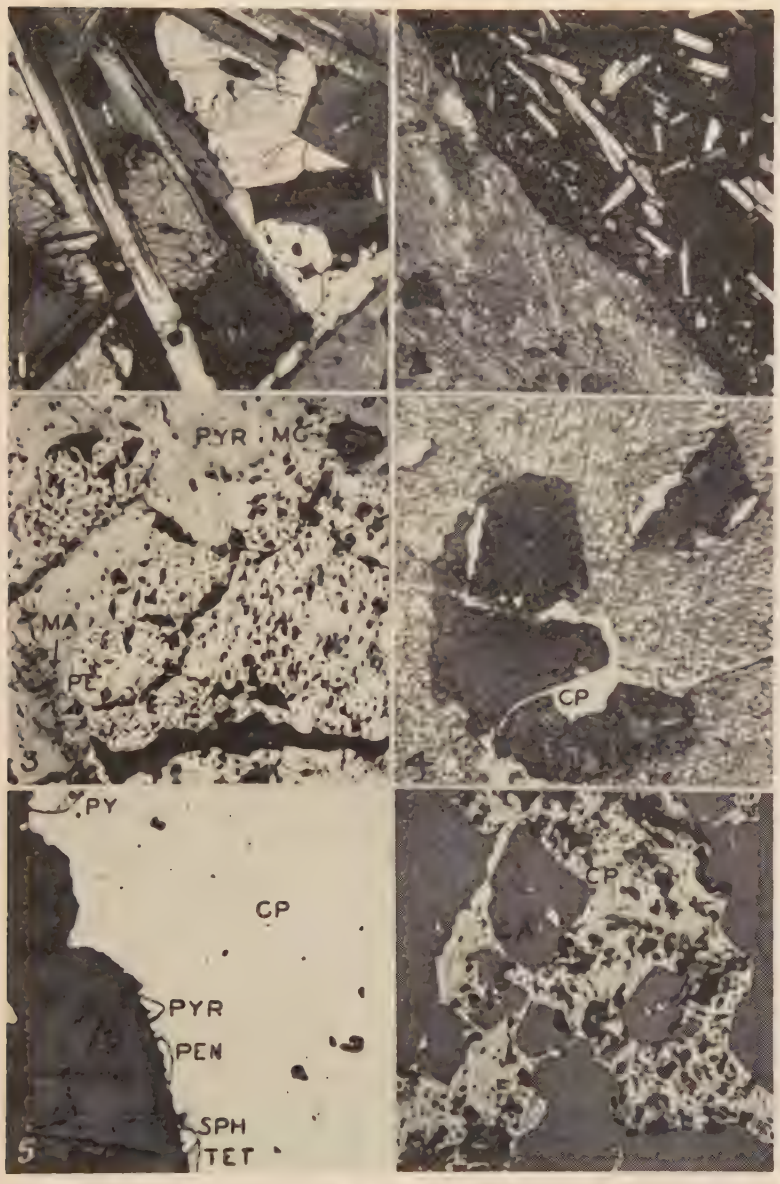
Fig. 2. Chilled contact of the Keweenawan diabase (black) against the older, altered Haileyburian peridotite; plagioclase laths parallel to the contact. × 20.

Fig. 3. Unaltered pentlandite (rough) within massive pyrrhotite (smooth). Marcasite stringers developed at right angles to a fracture in pyrrhotite. × 20.

Fig. 4. Carbonate enclosing crystals of magnetite (black) fractures which are filled and partly replaced by chalcopyrite (white). × 20.

Fig. 5. Chalcopyrite in contact with carbonate gangue, with intervening sphalerite, pyrrhotite, pentlandite and tetrahedrite. × 20.

Fig. 6. Chalcopyrite enveloping rhombs of calcite (gray). × 20.



FIGS. 1–6.

Violarite.—Violarite (Fig. 7), a supergene nickel sulphide replacing pentlandite and pyrrhotite, is the most interesting mineral found in the ores. It is associated with the massive pentlandite, but only rarely replaces the thin stringers of light-colored pentlandite within the pyrrhotite. In the massive pentlandite the unreplaced portions remain as islands within the network of violarite. High power reveals that violarite-pentlandite masses are a mixture of violarite and unreplaced pentlandite.

The network of fractures, as well as the cleavage cracks within the pentlandite, served as channelways for the replacing nickel sulphate solutions. Along contacts between pyrrhotite and pentlandite, the violarite may replace both minerals (Fig. 3).

Pyrite.—Pyrite is commonly present and euhedral crystals occur within pyrrhotite and are replaced by it (Fig. 8).

Sphalerite.—Sparse sphalerite, both the yellow and black varieties, is closely associated with pentlandite and pyrrhotite. Thin streamers of sphalerite within the pyrrhotite probably indicate that it is later than the pyrrhotite (Fig. 5).

Magnetite.—Magnetite, although not abundant, is of interest because it was formed at three different periods, namely: (1) from the original olivine-peridotite magma; (2) secondary after olivine and other ferro-magnesian minerals; (3) one of the first minerals formed from the mineralizing solutions. The three types differ notably in occurrence. The original magnetite of the unaltered olivine-peridotite is present as rounded, fractured

---

Fig. 7. Pentlandite completely altered to violarite, which is replacing pyrrhotite along the fracture. × 20.

Fig. 8. Fractured chlorite blades occupied and penetrated by sulphides. × 20.

Fig. 9. Association of pyrrhotite, violarite, chalcopyrite and pyrite. × 20.

Fig. 10. Pyrrhotite (white) associated with and later than chlorite (gray). × 20.

Fig. 11. Calaverite in pyrrhotite. Oil immersion.

Fig. 12. Blades of chlorite (white) associated with the first generation calcite (rhomb), both enveloped by sulphide (black), indicating pre-sulphide alteration. × 80.

FIGS. 7-12.

grains, and in a few cases, is nearly replaced by other minerals. The magnetite produced by the alteration of olivine and other ferro-magnesian minerals occurs as long stringers through the gangue rock. The third and most abundant type is associated with the sulphides in euhedral or rounded, equidimensional grains, scattered throughout the pyrrhotite (Figs. 4, 3).

Marcasite.—Marcasite was observed in most of the sections, but quantitatively it is unimportant. It occurs in two forms: (1) large rounded masses within pyrrhotite; (2) long ridge-like bodies in pyrrhotite. The second occurrence is the most interesting, because it forms a series of parallel "hogbacks" rising above the pyrrhotite, and apparently developed along the basal partings of the pyrrhotite. Where marcasite is in contact with magnetite, small, veinlike areas of blue-gray hematite are developed between the two minerals (Fig. 3).

Hematite.—Hematite is not abundant but one interesting mode of occurrence should be mentioned. Under the descriptions of "violarite" and "pentlandite" attention was called to the numerous fractures throughout these minerals in which, and at a later stage of mineralization, hematite had developed.

Calaverite.—Within the massive pyrrhotite a few minute grains of a yellowish-white mineral were found, which etch tests indicate is one of the gold-silver tellurides. It is called calaverite upon the basis of occurrence and color, but the areas are too small to permit satisfactory microchemical tests. This mineral is contemporaneous with the pyrrhotite of Cuniptau, but in other nickel ores most tellurides are later than pyrrhotite (Fig. 11).

Sperrylite.—There were two small crystals of a hard, grayish-white mineral found associated with the sphalerite and pyrrhotite. Physical and etch tests indicate that it is the platinum diarsenide, sperrylite. It apparently is contemporaneous with the associated sulphides.

Chromite.—Chromite, present in the original unaltered peridotite, is closely associated with the primary magnetite. With the alteration of the olivine-rich peridotite much chromite is developed as veinlets through serpentine pseudomorphs.

Summary of Age Relations.—Magnetite and chromite are the only metallic minerals remaining from the original rock. Secondary silicates, carbonates, magnetite, and chromite were developed before the introduction of the ore minerals.

The first introduced mineral was magnetite. Pyrrhotite, sphalerite, calaverite, and tetrahedrite were apparently contemporaneous. Pentlandite was formed along with pyrrhotite and continued to be deposited later than it. Chalcopyrite encloses crystals of pyrrhotite, pentlandite and tetrahedrite. Violarite replaced pentlandite at a late stage. Marcasite is present only within the pyrrhotite, which makes it difficult to determine its age relation to the other minerals. It is secondary and probably developed at the time the violarite replaced the pentlandite.

Most of the calcite is older than the ore minerals, but there is a second generation of calcite that cuts the older calcite crystals and fills fractures in pentlandite and violarite. Along with the second generation of calcite, hematite crystallized within the fractures of the pentlandite and violarite; it is later than most but not all of the violarite. Some violarite is definitely later than the hematite.

SOURCE OF THE ORE SOLUTIONS.

No direct evidence was noted to indicate that the younger Keweenawan dikes played any part in the mineralization of the Haileyburian peridotite. The metallization was presumably older than the Keweenawan dikes, and may have originated from the peridotite magma chamber.

Within the area, but not on the Cuniptau property, several other igneous rocks outcrop. These rocks are younger than the Haileyburian peridotite and older than the Keweenawan dikes. They include Algoman granite, Matachewan diabase dikes, and Nipissing diabase. It is of course possible, but not probable, that the igneous activity of one of these periods was responsible for the alteration and mineralization of the older Haileyburian peridotites.

Composition of the Mineralizing Solutions.—Immediately following the magmatic stage of the Haileyburian peridotite the first

important solutions penetrated the rocks of the Cuniptau area. These solutions quickly altered the newly formed olivine-rich peridotites to serpentine, chlorite, talc, carbonates, and white micas. At this time the solutions contained the following compounds and ions, either free or combined in various combinations, SiO_2, CO_2, Al, Mg, Na, Ca, Fe, Ti, K, and H_2O.

The metallization followed the alteration of the peridotites, and in this period the solutions carried the following compounds and ions, either free or combined, Cu, Zn, Pt, Au, Ag, Te, Fe, Ni, Sb, Ca, Mg, SiO_2, H_2S, CO_2 and H_2O.

SUMMARY.

The general geology at Cuniptau is similar to that of many other mining localities between North Bay and Kirkland Lake, Ontario. The basement complex is unknown. Upon the eroded surface of this basement is a great thickness of younger lavas, which range from acid to base. Some of the flows are vesicular and others are amygdaloidal. Deformation followed soon after the last flows, and now the highly-folded Keewatin lavas have steep dips ranging from 60 to 80 degrees.

After this folding, a mass of olivine-rich peridotite intruded the Keewatin flows. At present this rock is so highly serpentinized, chloritized, and recrystallized, that none of the original silicates remain.

There are no rocks present, younger than the Haileyburian peridotite and older than the late Keweenawan olivine-diabase dikes. The period between the intrusion of the two was long enough to allow a complete alteration of the Haileyburian before it was cut by the dikes, which are remarkably fresh.

Considerable deformation, folding, and fracturing followed the alteration of the peridotite, and permitted the introduction of the ore minerals. These were deposited before the barren Keweenawan dikes were intruded, since the latter cut both the Keewatin lavas and mineralized peridotite.

The ore minerals were deposited as fracture fillings and replacements in the altered peridotite, which was completely altered

before the sulphide-bearing solutions entered. There were three distinct periods of mineralization: (1) early alteration of the Haileyburian peridotite with the development of many secondary minerals; (2) the introduction of the sulphide-bearing solutions and the deposition of the ores; (3) the supergene deposition of violarite, marcasite, hematite, and calcite. Oxidation of the sulphides left a rusty gossan, which first attracted attention to the property.

MIAMI UNIVERSITY,
OXFORD, OHIO,
Jan. 10, 1942.

LANCASTER PRESS, INC., LANCASTER, PA.